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Perceived indicators of climate change in Tanzania: insights from the university of Dodoma students

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Abstract

Background Understanding local communities' knowledge and insights is essential for developing effective mitigation and adaptation strategies for climate change. The young generation often brings new perspectives on climate change, demonstrating a growing awareness of its impacts and innovative ideas for sustainable solutions. By engaging youth in climate action we foster future leadership, empowering them as active participants in shaping long-term climate resilience. Higher education plays a pivotal role in raising awareness about climate change and fostering environmentally responsible behaviour among citizens. Thus, the study assessed climate change indicators in Tanzania by gathering insights from university students, leveraging their understanding of the local challenges posed by climate change.

Results Out of the 486 sampled students, 80% were aware of climate change and could identify its indicators in their home regions. The primary perceived indicators of climate change reported by the respondents included increasing temperatures, crop failures, and the disappearance of native plant species. Respondents from the coastal zone ranked rising temperatures and increased rainfall as the most significant indicators, while those from the Kilimanjaro region emphasised crop failure. Additionally, respondents from the central zone highlighted the disappearance of native plant species. Conversely, respondents from the arid central zone believed that climate change has resulted in reduced rainfall and an increase in drought occurrences. Furthermore, socio-demographic factors such as gender, home region, and academic year influenced students' awareness of climate change. A lower proportion (0.78) of male students demonstrated knowledge of climate change compared to female students (0.91) ($p = 0.001$). Additionaly, a lower proportion (0.71) of students from urban areas demonstrated knowledge of climate change compared to students from rural areas (0.85) ($p < 0.001$). Moreover, students in their final year of study exhibited greater awareness of climate change than those in lower years, highlighting the significance of the formal education system in imparting knowledge about climate change.

Conclusions This study underscores the role of higher education in fostering climate awareness and youth engagement through education and outreach. Additionally, it supports SDG 13: "Climate Action" and SDG 4: "Quality Education by promoting informed participation and sustainable solutions among young people".

Keywords Climate change awareness, Educational interventions, Perceptions of climate change, Socio-demographic factors, University students

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Background

Climate change is one of the key global issues of the twenty-first century due to its profound impacts on humans and ecosystems [1, 2]. Various changes happening on the earth provide insights into the ongoing alterations in the earth's climate system. These indicators encompass a variety of observable phenomena, including rising global temperatures, shifting precipitation patterns, increased frequency and intensity of extreme weather events, and the melting of glaciers and ice caps [3–5]. Average global temperatures have risen significantly over the past century, with the past few decades witnessing unprecedented warmth [3, 6, 7]. Global warming is causing extreme heat, storms, and wildfires, and increasing disease vectors, harming ecosystems as well as human health [8–10]. Additionally, the changes in seasonal weather patterns have led to altered agricultural productivity and water availability in various regions due to prolonged droughts [11–13]. Together, these indicators highlight the urgency of addressing climate change and underscore the importance of climate awareness and education in fostering resilience, as well as developing comprehensive mitigation and adaptation strategies.

While the effects of climate change are felt worldwide, the poorest countries and people are more affected, as they are more exposed to and vulnerable to the impacts [14–16]. Sub-Saharan Africa relies significantly on agriculture for livelihoods; hence, changes in temperature and precipitation patterns can cause alterations in crop adaptability, compromising food security and economic stability [16–18]. Tanzania is among the countries most vulnerable to the impacts of climate change due to its dependence on climate-sensitive sectors like agriculture, fisheries, and tourism [19, 20]. The country is now witnessing significant weather extremes as a result of a changing climate [20–22]. Increased temperatures, floods, prolonged droughts, and erratic rainfall are resulting in significant impacts on agriculture, energy, infrastructure, biodiversity, fresh water resources, health, and livelihoods [19, 20, 23]. Climate projections show that the western regions, southern highlands, and central parts of Tanzania will be warmer by more than 2 °C by 2041, while the eastern zone will experience a temperature increase of 1 °C [19, 22]. Population growth has heightened the demand for agricultural land and fuel for household cooking, leading to increased deforestation [24–26]. Poorer households, particularly in rural areas, are disproportionately affected since they rely on climate-sensitive economic activities such as rain-fed agriculture, herding, and fishing for a living [27, 28]. Nevertheless, local populations have a significant role to play in combating climate change, despite their vulnerability [29].

Tapping local knowledge of climate change has been advocated in recent years [29, 30]. The insights and knowledge of communities can provide valuable data about local climate change, which is necessary for formulating mitigation and adaptation measures [31, 32]. While local knowledge is often documented, the perceptions and observations of younger generations who are key stakeholders in future climate action remain underexplored. Understanding how youth, particularly students, perceive climate indicators can reveal gaps in awareness and inform targeted educational initiatives. Young adults are the future leaders, policymakers, scientists, and professionals who will be responsible for addressing the challenges of climate change [33, 34]. Thus, gathering data from young adults can inform their understanding, concerns, and perspectives on climate change, shaping education, policy, and action plans. Higher education is crucial in raising awareness about climate change and encouraging environmentally responsible behaviour among students and citizens. University students, in particular, are actively engaged in learning about climate change through various disciplines. Despite having less experience, the skills they acquire enable them to analyse and interpret changes happening in their surrounding environment [35, 36]. Furthermore, university students come from various regions with different backgrounds, cultures, and experiences. Gathering climate change data from such a diverse student population can provide a wide range of perspectives, experiences, and knowledge in a short period of time.

This study aligns with both national and global policy frameworks focused on climate action, education, and sustainable development. At the global level, it supports SDG 13 (Climate Action), particularly Target 13.3, which emphasizes improving climate change education and awareness [37, 38]. It also aligns with SDG 17 (Partnerships for the Goals), which fosters collaboration across sectors for sustainable development. This study also aligns with national policy frameworks that focus on climate action, education, and sustainable development. The National Adaptation Programme of Action (NAPA) emphasizes the need for climate adaptation strategies in vulnerable sectors such as agriculture, water, and biodiversity, which this study supports by gathering insights on perceived local climate indicators and their potential role in driving adaptation [39]. The Tanzania National Environmental Policy highlights the importance of integrating climate change awareness and education into national planning and development processes, aligning with the study's focus on enhancing youth knowledge of climate change impacts [40, 41]. By emphasizing youth voices, the study highlights the critical role of education and collaboration in building resilient communities and achieving sustainable environmental outcomes.

The study aimed to assess university students' perceptions of climate change indicators across various regions of Tanzania, with a focus on identifying region-specific indicators and informing future educational and policy initiatives for climate action. Specifically, the study aimed to (a) determine university students' awareness and understanding of climate change indicators across different regions in Tanzania; (b) determine the factors influencing university students' awareness of climate change indicators, including demographic, educational, and place of residence; and (c) identify region-specific climate change indicators as perceived by students. The findings of this study offer valuable insights for educational institutions, policymakers, and stakeholders to assess the education system and devise climate change mitigation strategies.

Materials and methods

Study area

Tanzania is located along the eastern coast of Africa, positioned south of the equator, spanning roughly from 1.0° to 12.0° south latitude and 29.0° to 41.0° east longitude [42]. Tanzania comprises the mainland and the islands of Zanzibar, Pemba, and Mafia (Fig. 1). The 2022 population and housing census shows that the population of Tanzania is 62 million, an increase of 37% from 2012 [43]. Tanzania has a predominantly tropical climate characterised by a wet and a dry season. Temperatures range from about 18 °C to 29 °C year-round. Nevertheless, regional disparities exist due to the topography, with temperatures in the highlands typically ranging from 10 to 20 °C. The short rains usually begin in October and last until early December, while the long rains usually begin in March and last until May [42]. Yearly rainfall typically ranges from 550 mm in the centre to up to 3500 mm in certain areas of the southwestern highlands [44].

Tanzania's diverse vegetation, shaped by its varied climate and geography, supports a wide array of ecosystems, habitats, and biodiversity. This includes savannas with scattered trees and shrubs, highland montane forests, eastern tropical rainforests, coastal mangroves, and central semi-arid scrublands, as well as wetlands and grasslands [44–46]. This vegetation, particularly forests and mangroves, acts as a carbon sink, absorbing carbon dioxide from the atmosphere through photosynthesis and storing it in plant biomass and soil. In addition, vegetation helps to prevent soil erosion by stabilising soil with its roots and reducing runoff during heavy rainfall events. Yet, the expansion of agriculture, logging, development, and other human activities contributes to the destruction of forests [47].

The study was conducted by interviewing students enrolled at the University of Dodoma pursuing different undergraduate degree programmes. These students were from both the Tanzanian mainland and Zanzibar (Fig. 1). The University of Dodoma is a public university

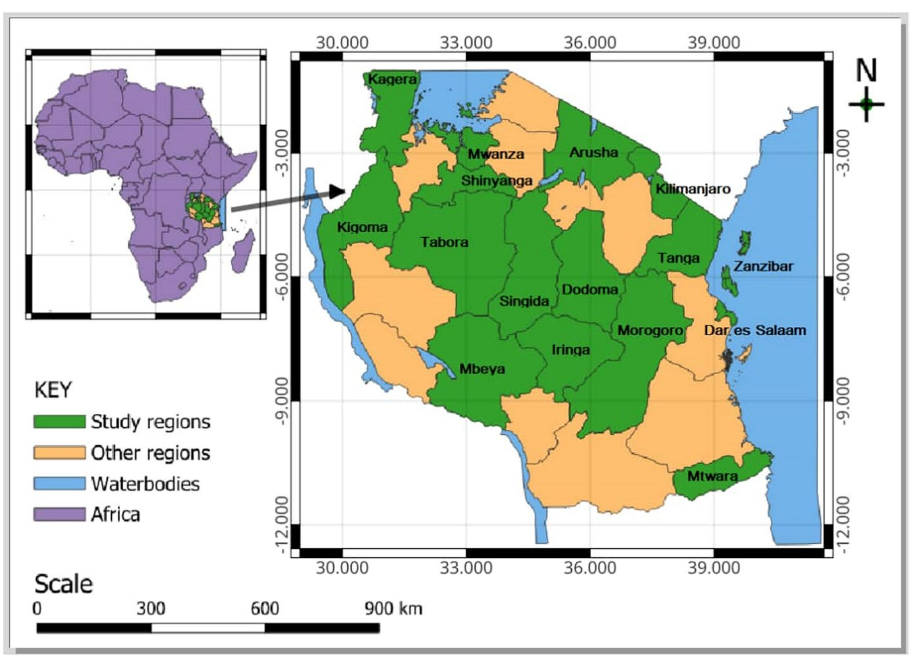

Fig. 1 A map of Tanzania showing home regions of the students interviewed

established in the Dodoma region of Tanzania in 2017. It is the biggest university in Tanzania, with the target of enrolling over 40,000 students. The university provides a wide range of undergraduate and postgraduate programmes spanning multiple fields such as arts and humanities, social sciences, natural sciences, engineering, business, and education.

Study design

A cross-sectional study design was utilised to collect data on climate change perceptions and perceived indicators in Tanzania. Data were gathered from undergraduate students at the University of Dodoma using self-administered questionnaires to capture their perspectives on climate change in their respective hometowns. Given the university's diverse student body from various regions of Tanzania, this approach facilitated the collection of data from a broad spectrum of the country.

Study population and sampling procedures

The population of the study comprised all bachelor students enrolled at the university was estimated at 30,000. We calculated a sample size by using Slovin's formula, which is given as $n = \frac{N}{1+N(e)^2}$ where: where n = sample size, N = study population, and e = sampling error [48]. A sample of 395 students was required for this study, based on a margin of error of 5%. We sample students from six colleges, 100 from each college, to increase the chance of getting the required sample. A simple random sampling technique was employed to select the participants. Lists of registered students from each college were acquired, and each student was assigned a unique number. Random numbers were generated using Microsoft Excel 2016, and students corresponding to these random numbers were chosen for inclusion in the study. Ultimately, 523 of the selected students agreed to participate, and questionnaires were distributed to them. However, the final sample size for the study consisted of 486 students who returned completed questionnaires. The students are from the College of Health and Allied Sciences (CHAS), the College of Humanities and Social Sciences (CHSS), the College of Informatics and Virtual Education (CIVE), the College of Natural and Mathematical Sciences (CNMS), the College of Business and Economics (COBE), and the College of Education (COED).

Data collection

Data collection was conducted in February and March 2023 using a self-administered questionnaire. The questionnaire included both closed-ended and scaled questions. We chose this method because pre-testing of the questionnaire indicated that face-to-face interviews were not convenient due to the tight class schedules of the students. We also realised that anonymity was important in encouraging students to share their views more honestly without feeling embarrassed. The interviews gathered data about the social-demographic aspects of the respondents and their perceptions about climate change in their home region (home region means where they were born and grew). The students were asked if they had heard about climate change and their views about its occurrence in their home regions. The students were also asked to identify specific indicators of climate change they had observed in their home region. A five-point Likert scale was then used to give a score of the identified perceived indicators of climate change in their home place. The scores are based on five-point bipolar choices on a scale of 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, and 5 = strongly agree about the indicators of climate change. The respondents were informed about the privacy and confidentiality of the data given.

Data analysis

The data was coded in Microsoft Excel for viewing. Descriptive statistics, such as frequencies and percentages, were utilised to summarise demographic data about the respondents. Additionally, the mean score of perceived climate change indicators, based on the Likert scale, was calculated using Microsoft Excel 2016. The data was then imported into R version 4.3.2 for further analysis. To compare the mean scores of various climate change indicators across different regions, an analysis of variance (ANOVA) was conducted. If the ANOVA results indicated a p-value less than 0.05, a Bonferroni post-hoc test was used to identify which specific regions showed significant differences in their mean scores. Further, we employed logistic regression to determine the associations between the perception of climate change and demographic characteristics (age, gender), year of study, home locality (urban or rural), and the college where the students were enrolled. The response variable was coded as 0 and 1, where 0 denotes students who believe climate change is not occurring, and 1 denotes students who believe climate change is occurring in their home region. Model evaluation was done by the Hosmer–Lemeshow goodness of fit test and pseudo-R square [49, 50]. Both methods indicated that the model fit well with the data.

Results

Social-demographic characteristics of the respondents

A total of 486 bachelor students from 15 regions of mainland Tanzania and Zanzibar were interviewed (Table 1). The highest number of students were from the Mwanza and Arusha regions. This regional representation provided diverse insights into climate change

Table 1 Regions where the interviewed students came from

Region	Zone	Frequency
Mwanza	Lake zone	52
Arusha	Northern zone	48
Dar es Salaam	Coastal zone	40
Dodoma	Central zone	40
Kilimanjaro	Northern zone	34
Shinyanga	Lake zone	32
Singida	Central zone	32
Mbeya	Southern highlands	28
Kagera	Lake zone	26
Iringa	Southern highlands	24
Morogoro	Coastal zone	24
Tabora	Central zone	24
Kigoma	Western zone	22
Mtwara	Coastal zone	20
Tanga	Northern zone	20
Zanzibar	Zanzibar	20

Table 2 Demographic aspects of the respondents

Variables	Parameter	Frequency	Percentage
Gender	Female	210	43.2
	Male	276	56.8
Age (yrs)	18—20	84	17.3
	21—23	276	56.8
	24—26	108	22.2
	Above 26	18	3.7
Year of study	1	156	32.1
	2	206	42.4
	3	124	25.5
College	CHAS	80	16.5
	CHSS	86	17.7
	CIVE	72	10.7
	CNMS	82	21.0
	COBE	78	16.0
	COED	88	18.1
Area of residence	Rural	220	45.3
	Urban	266	54.7
Do you think climate change is happening at your home place?	Yes	388	79.7
	No	98	20.2

perceptions, influenced by the varying climatic and socio-economic conditions across these areas.

The distribution of the respondents across gender, age groups, year of study, and area of residence is shown in Table 2. The majority of the students were males, aged 21–23 years old, and were in their second year of study. About 80% of the students perceived that climate change was happening in their home region (Table 2).

Perceived indicators of climate change

The students identified 16 climate change indicators (Table 3). Raising temperatures, crop failure, and the disappearance of native plant species were the highest-ranked perceived indicators of climate change (Table 3). Rising temperature was highly ranked as an indicator of climate change in Tanga (4.3), Zanzibar (4.2), Dar es Salaam, and Morogoro (4.0). However, comparison between the 16 regions was not significant ($p=0.143$). Post hoc pairwise comparison indicated that the scores were significantly higher in Tanga compared to Arusha ($p=0.026$), Iringa ($p=0.041$), and Mbeya ($p=0.039$). The scores for crop failure as an indicator of climate change were high in the Kilimanjaro region (4.2), Mbeya (4.1), Shinyanga (4.1), and Tanga (4.0). The difference between the 16 regions was statistically significant ($p=0.001$). Pairwise comparison of means showed that the scores were significantly higher in the Kilimanjaro region compared to Morogoro ($p=0.004$), Mtwara ($p=0.029$), Mwanza ($p=0.031$), and Tabora ($p=0.004$). The scores differed significantly between the 16 regions ($F15,470=2.508$, $p=0.001$). Further, disappearance of native plant species was ranked higher in Tabora and Tanga (4.0). The difference between the 16 regions was not significant ($F15,470=1.598$, $p=0.075$). Pairwise comparison showed that the scores were lower in Dodoma compared to other regions ($p<0.05$). Changes in the onset of rainy season had the highest score in the Mbeya and Mwanza regions (4.0), but the difference between all regions was not statistically significant ($F15,470=1.416$, $p=0.141$). However, pairwise comparisons indicated that the scores were significantly lower in Tabora compared to Arusha ($p=0.012$), Kagera ($p=0.015$), Kilimanaro (0.039), Mbeya ($p=0.008$), and Mwanza ($p=0.004$). More data is given in Table 3.

Factors associated with climate change perception

Logistic regression analysis was used to determine variables associated with climate change perception based on the question, 'Do you think climate change is affecting your place of residence?' The results show that gender, year of study, and home locality (rural or urban) determined the perception of climate change (Table 4). Male students ($OR=0.22$, $p<0.001$) and those from urban areas ($OR=0.4$, $p=0.001$) demonstrated a lower likelihood of perceiving climate change occurring in their home region (Figs. 2a and 2b). Further, students in their final year of study (third year) were more likely to perceive climate change happening in their home place ($OR=2.8$, $p=0.041$) compared to those in their first and

Table 3 Mean scores of the indicators of climate change in each study region on the Likert scale

Indicators	Arusha	Dar es Salaam	Dodoma	Iringa	Kagera	Kigoma	Kilimanaro	Mbeya	Morogoro	Mtwara	Mwanza	Shinyanga	Singida	Tabora	Tanga	Zanzibar	Mean	*p* value
Increase in temperature	3.4	4.0	3.8	3.3	3.6	3.7	3.8	3.4	4.0	3.8	3.5	3.5	3.8	3.8	4.3	4.2	3.7	0.143
Crop failure	3.3	3.9	3.4	3.5	3.5	3.6	4.2	4.1	3.1	3.3	3.5	4.1	3.9	3.1	4.0	3.7	3.6	0.001
Disappearance of native plant species	3.7	3.7	2.7	3.3	3.7	3.7	3.6	3.7	3.0	3.4	3.7	3.8	3.5	4.0	4.0	3.2	3.6	0.075
Changes in the onset of the rainy season	3.8	3.6	3.3	3.4	3.9	3.0	3.7	4.0	3.3	3.4	4.0	3.4	3.6	2.8	3.3	3.9	3.5	0.141
Reduction in forest cover	3.2	3.7	3.0	3.3	3.8	2.9	3.3	3.6	3.5	3.3	3.6	3.3	3.8	3.1	3.1	3.3	3.4	0.778
Water shortage	3.0	3.5	3.6	3.3	3.8	4.0	3.1	3.7	3.7	2.7	3.1	3.4	3.8	3.3	3.3	2.3	3.4	0.043
Decrease in precipitation	3.5	3.7	3.7	2.8	2.8	3.6	3.4	3.5	3.3	2.6	3.2	4.1	3.9	3.8	3.5	3.0	3.4	0.041
Reduction of grazing land	3.1	3.2	3.2	3.2	3.8	2.8	3.3	4.0	3.3	4.1	3.3	3.1	3.6	3.3	3.1	3.4	3.4	0.086
Shortening of growing seasons	3.7	3.6	3.0	3.3	3.6	2.8	3.6	3.6	3.3	3.2	3.3	3.4	3.6	3.6	3.4	2.5	3.3	0.478
Increased pests and diseases	3.7	2.5	2.9	3.7	3.5	3.3	3.4	3.2	3.3	3.4	3.2	3.1	3.4	3.6	2.9	3.5	3.3	0.193
Increased soil erosion	3.3	2.8	3.4	3.3	2.9	2.9	3.2	3.4	3.2	3.7	3.3	3.4	3.4	3.3	3.2	2.6	3.2	0.835
Increased human-wildlife conflicts	3.7	2.3	3.2	3.7	3.5	3.4	3.5	3.2	2.8	3.1	3.2	3.2	3.8	2.9	2.6	3.0	3.2	0.036
Bush fires	3.2	2.8	3.3	3.0	3.2	3.4	2.9	2.5	3.4	3.1	3.1	2.6	3.4	3.6	3.1	2.7	3.1	0.580
Increase in frequency of drought	2.8	2.6	3.8	2.4	3.0	2.8	2.9	2.4	3.2	3.3	3.1	3.6	2.7	3.4	2.8	1.7	2.9	0.009
Increase in frequency of floods	2.6	2.4	2.3	1.9	2.0	2.6	2.8	2.4	2.4	2.8	2.7	2.7	2.8	1.9	2.1	2.2	2.4	0.536

Table 3 (continued)

Indicators	Arusha	Dar es Salaam	Dodoma	Iringa	Kagera	Kigoma	Kilimanaro	Mbeya	Morogoro	Mtwara	Mwanza	Shinyanga	Singida	Tabora	Tanga	Zanzibar	Mean	*p* value
Increase in precipitation	2.9	2.9	2.5	2.7	3.2	2.6	3.0	2.9	3.0	2.9	2.6	2.6	2.6	2.9	2.7	3.4	2.8	0.933

Table 4 Factors associated with the perception of climate change occurrence among the respondents

Variable	Category	OR	SE	z	p	95% CI for the OR
Intercept		9.29	1.81	2.838	0.004	8.1—15.8
Gender	Female	0				
	Male	0.22	0.40	−3.798	< 0.001	0.1—0.7
Age		0.98	0.08	−0.212	0.831	0.8—1.2
Year of study	First year	0				
	Second year	1.76	0.39	1.455	0.145	0.8—1.2
	Third year	2.8	0.52	1.974	0.041	1.0—8.1
Home locality	Rural	0				
	Urban	0.40	0.37	−3.122	0.001	0.2- 0.8
College	CHAS	0				
	CHSS	0.75	0.29	0.529	0.591	0.3—2.1
	CIVE	2.14	0.38	0.688	0.267	0.6—9.1
	CNMS	1.74	0.25	0.559	0.318	0.6—5.3
	COBE	1.79	0.27	0.572	0.306	0.6—5.7
	COED	2.55	0.39	0.590	0.112	0.8—8.4

second years of study (Fig. 2c). However, no significant association was found between the perception of climate change and the students' field of study or age.

Discussion

The study investigated perceived climate change indicators among Tanzanian students from diverse regions, primarily aged 21 to 23. In the coastal region, increased temperature was most commonly perceived as a climate change indicator, followed by crop failure in the Kilimanjaro region, changes in the onset of the rainy season and the disappearance of native plant species in the central zone. Overall, most students were aware of climate change and believed it had occurred in their home regions. However, awareness was influenced by students' residency, gender, and academic year.

Awareness and perception of students regarding climate change

The majority of students in this study were aware of climate change and believed that it had affected the region of their residency. This finding is consistent with several studies that suggest increasing awareness of climate change among young people, particularly in regions that are experiencing visible environmental changes. For example, a study by Ofori et al. [51] in Ghana and Leal Filho et al. [52] across different continents found that university students exhibited a solid understanding of climate change, particularly concerning its effects on agriculture and water resources. Similarly, a study by Akrofi et al. [53] found that university students in Africa exhibited high awareness of climate change, often due to observable environmental shifts such as droughts, erratic rainfall, and biodiversity loss. These studies highlight that students' awareness often correlates with direct experiences of climate-related disruptions in their local environments. However, studies by Mugambiwa and Dzomanda [54] and Arlam et al. [55] in universities in South Africa found low levels of knowledge and awareness of climate change among students. The difference has been attributed to variations in educational curricula, local environmental experiences, or access to climate change data. To address these gaps, the studies recommended incorporating climate change topics into university curricula and establishing workshop programs focused on climate change awareness.

Factors associated with climate change awareness among the students

The results of this study highlight several key factors influencing climate change awareness among students. Notably, demographic characteristics such as gender, place of residence, and age significantly shaped students' perceptions and awareness of climate change. This aligns with previous studies, which have highlighted the role of gender, age, and place of residence in shaping individuals' perceptions and understanding of climate change [35, 51, 56]. Female students demonstrated higher awareness of climate change compared to male students and those from rural areas. In developing countries, women are particularly vulnerable to climate change impacts due to their prominent roles in agricultural production, water fetching, fuelwood gathering, and family care [57–59]. Thus, girls are more likely than boys to learn from their mothers by helping them with household tasks and participating in community activities. This finding aligns

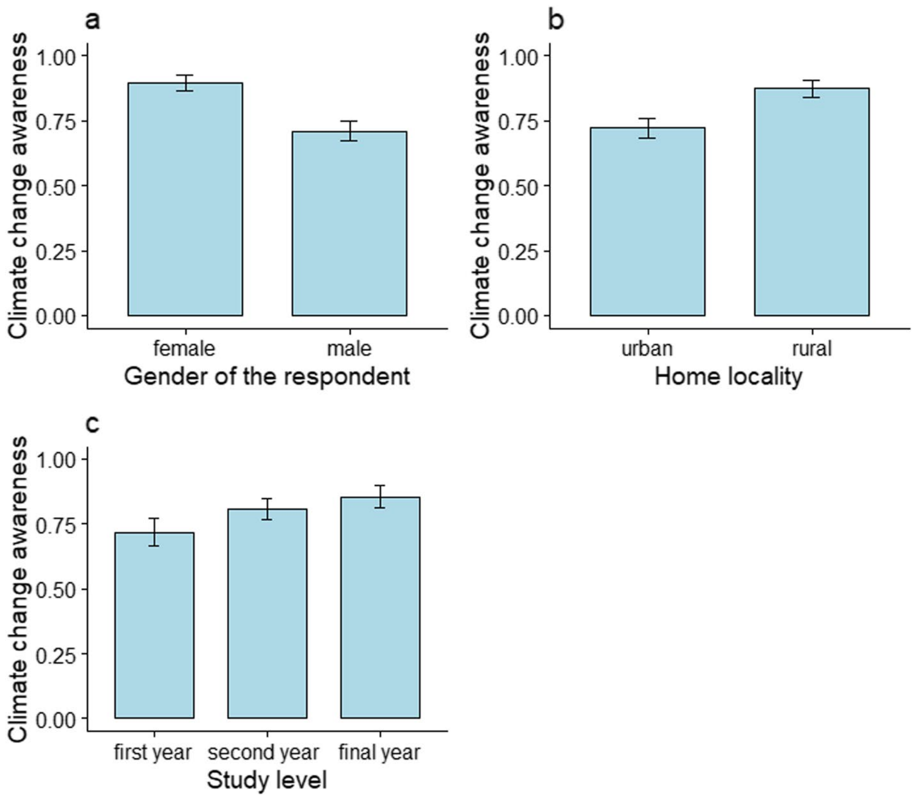

Fig. 2 The influence of (**a**) gender, (**b**) home location, and (**c**) academic year on students' likelihood of being aware of climate change

with previous studies in different parts of the world [52, 60, 61]. The higher awareness of climate change among female students highlights the potential of gender-responsive educational strategies to empower women (SDG 5). Given women's vulnerability to climate change in developing countries, targeted education can amplify their capacity to mitigate and adapt to its impacts.

Further, the students from rural areas demonstrated higher knowledge of climate change compared to those from urban areas. Rural communities in Tanzania primarily depend on agriculture and natural resources for their livelihoods. As such, they experience climate change impacts, such as droughts, crop failures, and altered weather patterns, more often [62, 63]. This direct experience may make rural students more attuned to climate-related issues and more likely to be aware of their effects. Additionally, rural communities have traditional knowledge passed down through generations related to weather patterns, farming techniques, and environmental changes, which can increase climate awareness [64, 65]. On the other hand, urban areas may experience climate change impacts such as floods and increasing temperatures but are less involved in agricultural activities [66–68]. The study by Dewi and Khoirunisa [69] also reported that rural students showed a greater understanding of climate change compared to their urban counterparts. Additionally, final-year students demonstrated higher awareness of climate change compared to those in earlier years, consistent with the findings of Ofori et al. [51]. The finding underscores the importance of incorporating climate change education throughout the entire academic curriculum. Initiatives such as workshops, campaigns, and experiential learning opportunities should be targeted at early-year students to bridge the awareness gap and prepare them to engage with environmental challenges throughout their studies and beyond. Increasing climate change awareness is critical to achieving SDG 13, as it cultivates a generation of individuals ready to take climate action. By addressing the demographic disparities in awareness, such as those based on gender and place of residence, policymakers and educators can create inclusive strategies that ensure no one is left behind in the global effort to combat climate change. These efforts collectively contribute to sustainable development by fostering equitable, educated, and resilient communities.

Perceived indicators of climate change by the student

The students identified several indicators of climate change, including rising temperatures, crop failure, and changes in rainfall patterns. These perceptions highlight students' awareness of environmental changes and their ability to relate local observations to broader climate change phenomena, emphasizing the importance of integrating their insights into climate education efforts.

Increasing temperature

Rising temperatures emerged as the most frequently perceived indicator of climate change across all regions, receiving the highest scores from students in the coastal regions. This consistent observation highlights the widespread awareness of increasing temperatures as a key manifestation of climate change [70–72]. The perception of increasing temperature is consistent with empirical evidence of temperature increases in Tanzania. The average annual temperature of the country is projected to increase by 1.0 °C to 2.7 °C by 2060 [73]. The coastal areas are experiencing higher temperatures [74–76]. The coastal regions' close proximity to the ocean and the intricate interplay between land, sea, and atmosphere heighten their susceptibility to the effects of rising temperatures [77, 78]. Over the past 30 years, temperatures in Zanzibar have been rising, with a strong increase in average and maximum temperatures [79, 80]. Apart from raising temperatures, coastal regions also experience increased rainfall variability, higher wind speeds, and excessive and rising sea levels [76, 80]. The changes impact local communities through disruptions to the marine ecosystem, storm surges, coastal erosion, and effects on agriculture caused by rising sea levels [81, 82]. Hence, monitoring and documenting climate change impacts in coastal areas is vital to identifying priority adaptation investments for strengthening local community and ecosystem resilience.

Crop failure

Crop failure was the second-ranked perceived indicator of climate change, with students from Kilimanjaro, Shinyanga, and Mbeya regions particularly emphasizing its significance. The students from the Kilimanjaro region pointed out that coffee and banana cultivation, prominent in the region, were significantly impacted. This observation coincides with prior studies indicating reduced coffee output in Kilimanjaro due to declining rainfall and rising temperatures [83, 84]. The productivity of coffee depends on optimal climatic conditions, such as a temperature range of 18–21 °C and an annual rainfall range of 1200–1800 mm [83]. In the Kilimanjaro region, mean annual temperatures have been increasing since the 1980s, while mean annual rainfall has been decreasing, affecting the production of coffee and other crops [83–85]. Episodes of drought, heavy rainfall, and delay in the onset of the rainy season affect the flowering, fruiting, and harvesting of coffee [83]. For optimum growth, bananas also need a sufficient amount of evenly distributed rainfall. The cultivation of bananas may be disrupted by changes in rainfall patterns, particularly adjustments to the time and intensity of the rain [86–88]. In contrast, the Mbeya region cultivates rice and maize, while the Shinyanga region grows cotton and paddy, both of which rely on favourable weather conditions for healthy growth and high yields. Implementing climate-resilient crop varieties, enhancing water management, adopting agroforestry systems, and promoting sustainable land use practices can benefit both banana and coffee crops.

Changes in precipitation

Students from the Shinyanga region perceived a decrease in the frequency and intensity of rainfall events, resulting in prolonged droughts and reduced water availability. In addition, students from the Dodoma region noted an increase in the frequency of droughts. Both regions, characterized by a semi-arid climate, are susceptible to the effects of climate change [89, 90]. The Dodoma region is characterized by rapid urbanization [91]. The urbanization has been shown to escalate the challenges posed by climate change if not well planned [92]. The increase in urban population and the construction of urban infrastructure exacerbate the overheating problem [93]. Additionally, the expansion of urban areas typically results in the destruction of natural habitats, reducing the capacity of ecosystems to mitigate climate-related risks such as floods and heatwaves [94, 95]. According to Sumari et al. [94], the expansion of Dodoma city has increased land surface temperature due to a decrease in vegetation cover. The temperature increase induced by urbanization intensifies drought [93]. However, the students from Zanzibar believed that climate change has led to an increase in precipitation. This belief could stem from observations of shifts in rainfall patterns, such as more frequent heavy downpours or extended rainy seasons, which are consistent with some climate change projections for tropical regions. The islands are experiencing significant rainfall variability, including extreme cases of heavy rainfall and strong winds [96, 97]. Additionally, Zanzibar is witnessing an increase in the frequency of monsoon flood events [98]. These events have a direct impact on fishing and seaweed farming, which are the primary economic activities of the local population, thereby intensifying their impact on livelihoods.

Water shortage

Water shortage was identified as the most significant indicator of climate change by students from the Kigoma region. The problem of water shortage is affecting many rural communities in Tanzania and is being intensified by the shrinking of water sources due to climate change.

The Kigoma region is part of the Lake Tanganyika basin, where declining water quality and levels affect both drinking water supplies and fisheries. The region is home to both a large local population and refugees, which intensifies pressure on already depleted water sources. Previous studies conducted by Mkama [99] and Mabhuye [70] in the Kigoma region found that local villagers linked water shortages to both population growth and a decline in rainfall. These findings highlight the growing pressure on water resources, with increasing populations demanding more water, while at the same time, changing climate patterns result in reduced rainfall. In addition, Msuya & Mahonge [100] found that respondents in the Kigoma region attributed the drying up of some water sources, such as natural springs, rivers, and waterholes, to a decrease in rainfall. Implementing effective water management practices, coupled with comprehensive climate adaptation strategies, is crucial for addressing these challenges and ensuring the long-term resilience of communities in Kigoma.

Disappearance of wild plants species, reduction of forest cover, and human-wildlife conflicts

Most students from Tabora and Tanga perceived climate change as causing the disappearance of native plants, while those from Kagera believed it reduced forest cover. Additionally, Singida students linked climate change to increased human-wildlife conflict, while Tabora students associated it with more bushfires. The majority of the above regions, except Tanga, are found in the central zone and are characterised by miombo woodlands, which are known for frequent and intense fires [101–103]. The Singida region borders the Rungwa-Muhesi-Kizigo Game Reserve, where crop raiding by elephants is common [104, 105]. Climate change alters habitats and reduces the availability of natural resources, forcing wildlife to venture into human settlements in search of food and water. Rising temperatures and changing rainfall patterns can lead to crop failures and water scarcity, further heightening competition between humans and wildlife for limited resources. This results in more frequent encounters and conflicts, as both wildlife and communities struggle to adapt to the shifting environmental conditions. Human activities through deforestation, urbanisation, bushfires, and agriculture induce plant alteration and the disappearance of some species [106]. The impacts of climate change are exacerbating these challenges, posing threats to forest communities, leading to the disappearance of native plant species, and contributing to an increase in human-wildlife conflicts [106, 107]. Climate change has altered agricultural practices and land use, leading to a competition for food resources between humans and wildlife, intensifying human-wildlife interactions [108, 109]. Thus, there is a need for integrated conservation strategies that address both climate change and human-wildlife conflict while promoting sustainable land use practices, habitat restoration, and adaptive management to mitigate the escalating competition for resources between humans and wildlife.

Soil erosion, pests, and diseases of crops

Climate change is significantly affecting agriculture in Tanzania, including the rise in crop pests, plant diseases, and soil erosion, which are exacerbating food security and livelihoods [110, 111]. Changes in temperature, shifting rainfall patterns, and increasing extreme weather events driven by climate change have significantly influenced pests, leading to the wider spread of pests such as the fall armyworm and desert locust [112, 113]. These pests, along with plant diseases, cause severe damage to crops such as maize, sorghum, and millet, threatening food production and increasing economic loss. Students from the Arusha and Iringa regions ranked pests and diseases among the highest indicators of climate change, reflecting growing concerns over the impact of these factors on agriculture in the regions. This aligns with observations from several studies highlighting the increasing prevalence of crop pests and diseases linked to climate variability, further exacerbating the challenges faced by farmers in these areas [111, 114, 115]. Students from the Mtwara region believed that climate change had caused soil erosion in their area. Mtwara, a coastal region, is also experiencing coastal erosion attributed to the impacts of climate change [116]. More frequent extreme weather events, including heavy downpours, can cause flooding, further damaging the soil [117]. Implementing effective climate adaptation strategies, such as improved pest management and sustainable farming practices, is crucial to mitigating these impacts and improving the resilience of Tanzania's agricultural systems.

Conclusion

The study showed that the majority of the students were aware of climate change and linked its impact to changes happening in their home region. Social demographic factors such as gender, place of residence, and year of study determined awareness of climate change. The study's findings suggest that policies should prioritize integrating climate change education across all academic years to ensure that awareness is consistent among students, regardless of their year of study. Addressing the socio-demographic disparities in awareness, such as lower climate change knowledge among male students and those from urban areas, could be achieved through targeted educational programs and outreach initiatives. Additionally, policies should encourage universities to tailor climate change education to reflect regional climate impacts, making it more relevant and engaging for students from different areas. Finally, governments and educational institutions should collaborate to provide funding and resources for climate change initiatives that engage students both academically and through hands-on community-based projects.

Limitations of the study

The study has several limitations that present opportunities for future research. First, it focused on students from a single university, which restricts the generalizability of the findings to a broader population of students from other institutions, regions, or countries. Expanding the sample to include multiple universities could offer a more comprehensive understanding of variations in climate change awareness. Second, the study did not consider cultural factors that may influence students' perceptions and knowledge of climate change, such as traditional ecological knowledge, cultural practices, or community beliefs, which are critical in shaping attitudes and awareness. Additionally, reliance on self-reported data introduces potential biases, such as social desirability bias, which may affect the accuracy of the results. Furthermore, the cross-sectional design provides a snapshot of awareness at a single point in time, without capturing changes over time or assessing the effects of educational interventions. Future research should address these gaps by employing longitudinal designs, including diverse student populations, and integrating cultural and socio-economic factors to offer a more holistic perspective on the determinants of climate change awareness.

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Authors' contributions
Both authors contributed to the conception and design of the study. Material preparation and data collection were performed by RPM. The data analysis was carried out by both authors. The first draft of the manuscript was written by RPM, and both authors commented on previous versions of the manuscript and approved the final manuscript.

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Data availability
The dataset used in this study can be obtained from the corresponding author upon a reasonable request.

Declarations

Ethics approval and consent to participate
The participation of the respondents was voluntary, and signed consent was obtained before the interviews. Ethical clearance for conducting the study was provided by the Institutional Research Review Ethics Committee of the University of Dodoma. A research permit letter with reference number MA/84/261/70/32 was offered.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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